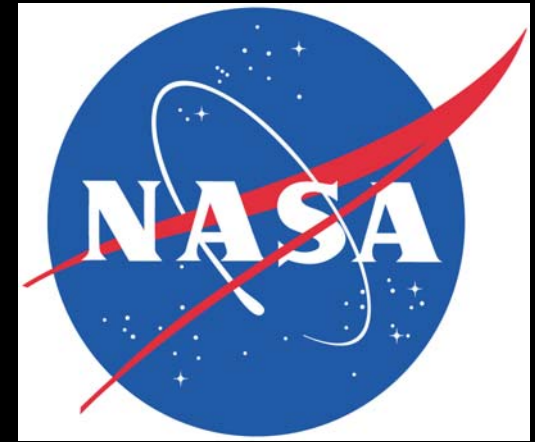
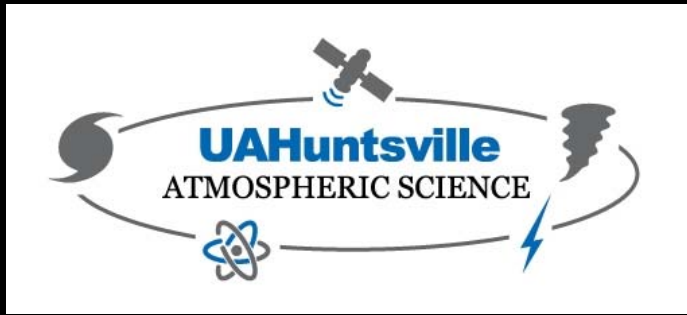




Total lightning observations within electrified snowfall using polarimetric radar LMA, and NLDN measurements

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Previous Work

- Limited studies of the in-cloud component : (Takeuti et al., 1978, Brook et al., 1982, Michimoto, 1993, Kitagawa and Michimoto, 1994)

- Rust and Trapp (2002) noted a normal dipole in electrified winter clouds

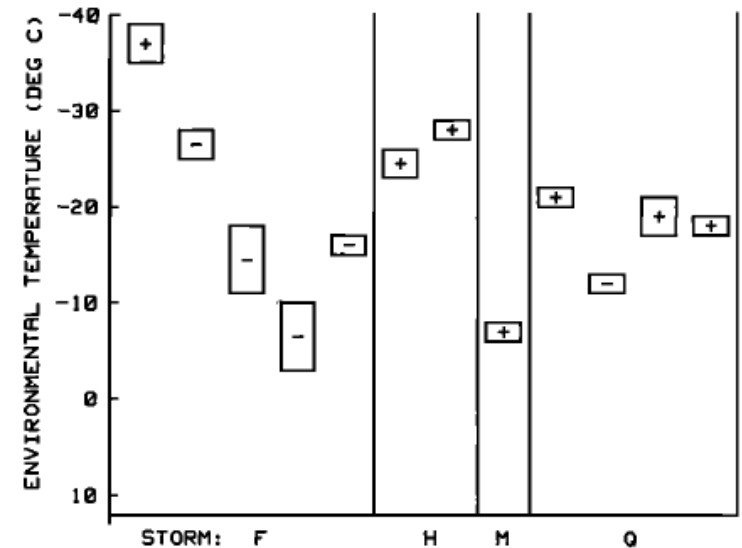


Fig. 10. Plot of the temperature height of the centers of charge for all strokes for which solutions were possible. The data are tabulated in Table 2. The temperature span in some of the strokes reflects the separate solutions obtained for different times into the continuing current interval.

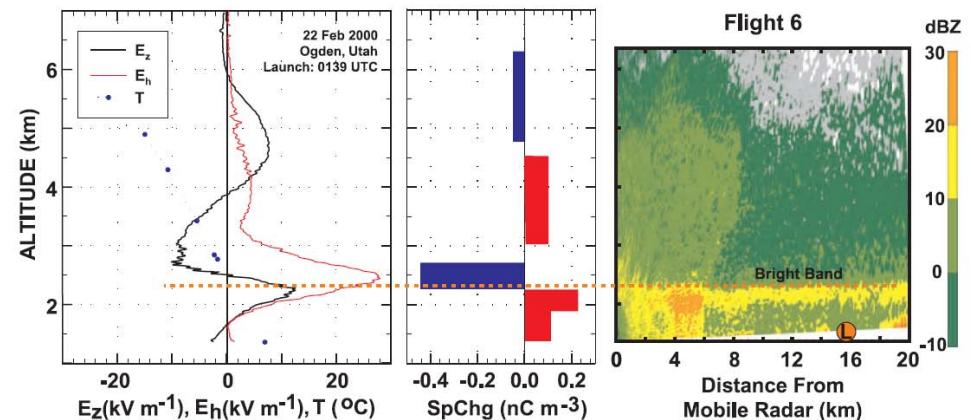


Figure 1. Example soundings in winter nimbostratus clouds. For each flight: Left panels are profiles of the vertical (E_z) and horizontal (E_h) components of the electric field, temperature (T), and dewpoint (T_d); middle panels are the space charge density inferred using Gauss's law; and right panels are the range-height-indicator radar reflectivity through the balloon launch location, L . All altitudes are MSL. The orange dashed line is the approximate top of the radar bright band. The >20 dBZ values in Flight 4 from 6–20 km and at 19 km in Flights 2 and 6 are from the foothills terrain.

Top: Figure 10 adapted from Brook et al. 1982

Bottom: Figure 1 adapted from Rust and Trapp 2002

Previous Work: Ground Based Measurements

- Several studies have used ground based measurements, namely the NLDN
 - Schultz 1999, Trapp et al., 2001, Dolif Neto et al., 2009, Market and Becker, 2009, Pettegrew et al., 2009, Steiger et al., 2009

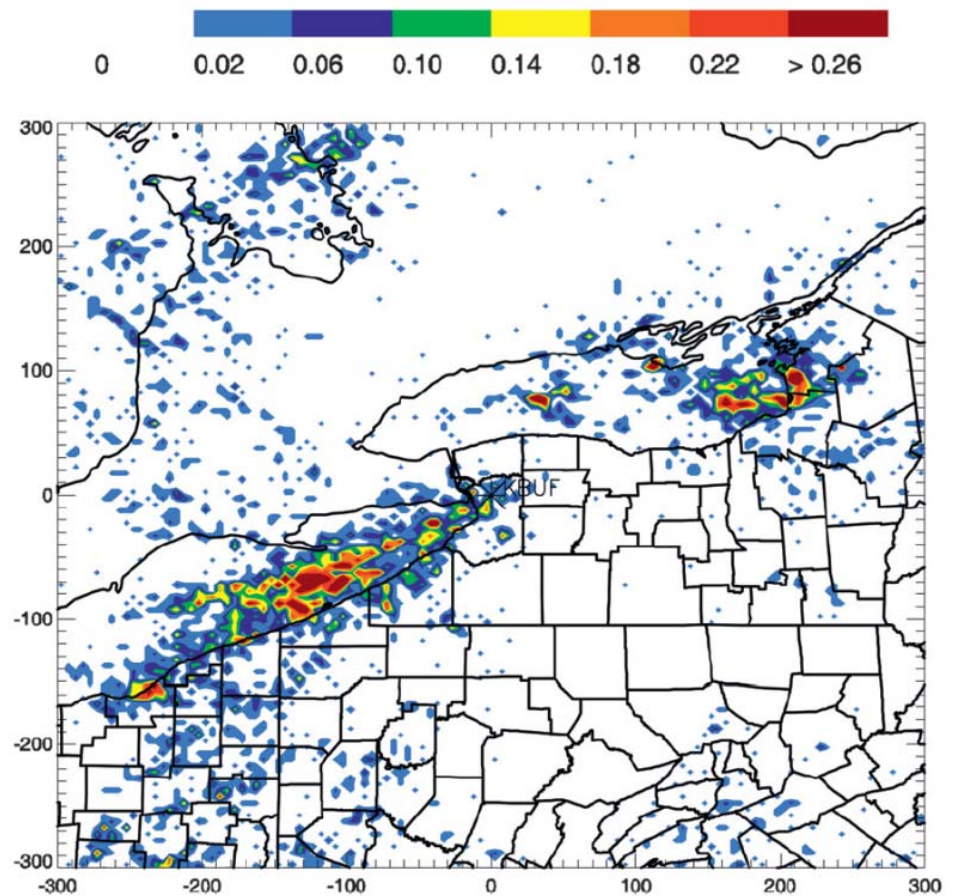
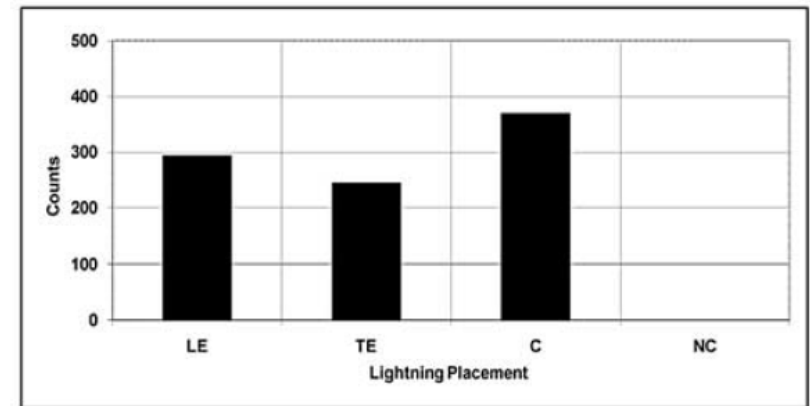


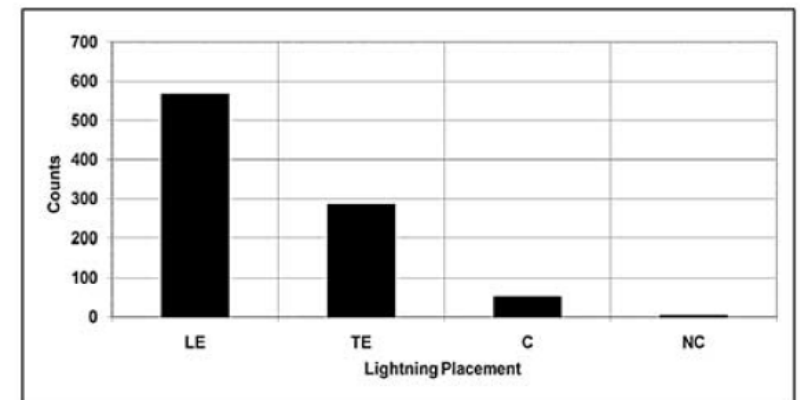
FIG. 2. The CG lightning-flash density (flashes per square kilometer) in the lower Great Lakes for all lake-effect storms during the 1995–2007 period centered on KBUF. The U.S. county outlines and the lakeshores are shown in black. Distances (km) south–north and west–east of Buffalo are also shown.

Market and Becker 2009, GRL

- Noted that CG flash location tended to be 15 km outside of the heaviest snowband.
- They noted that the flashes were in the center of the axis of the snowband (a).
- But...that the majority of the lightning was on the leading edge of the maximum reflectivity (b)



a



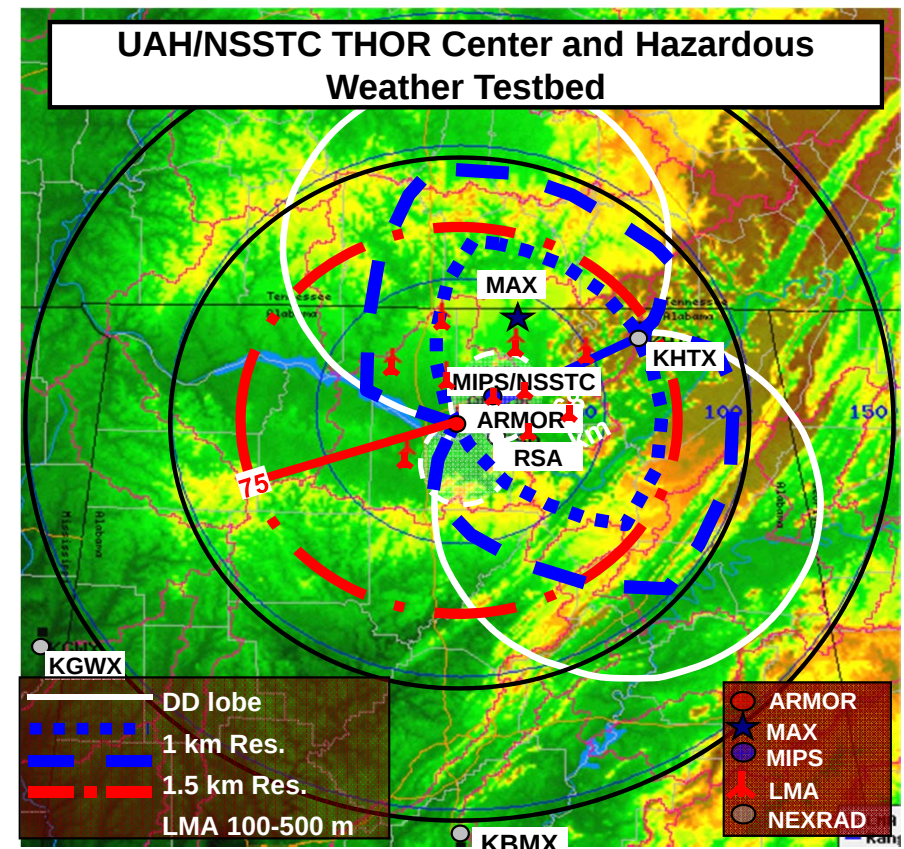
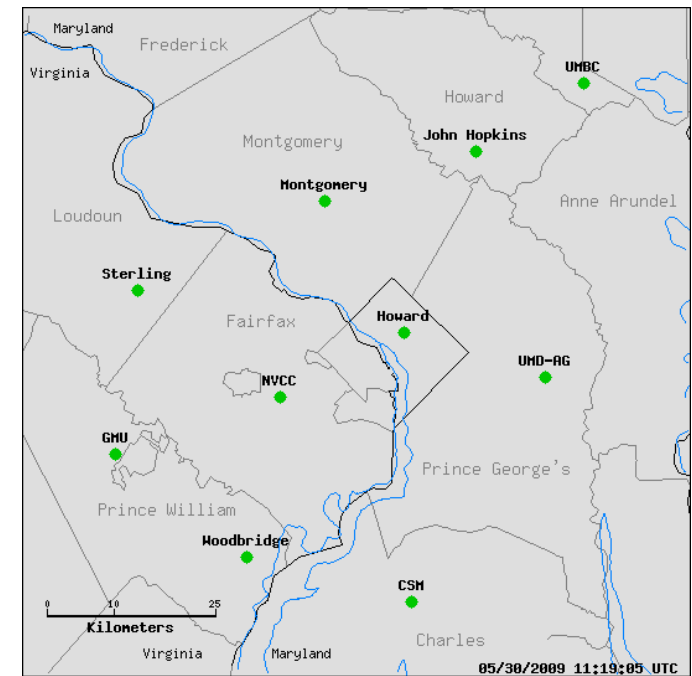
b

Adapted from Fig. 3 Market and Becker 2009, GRL

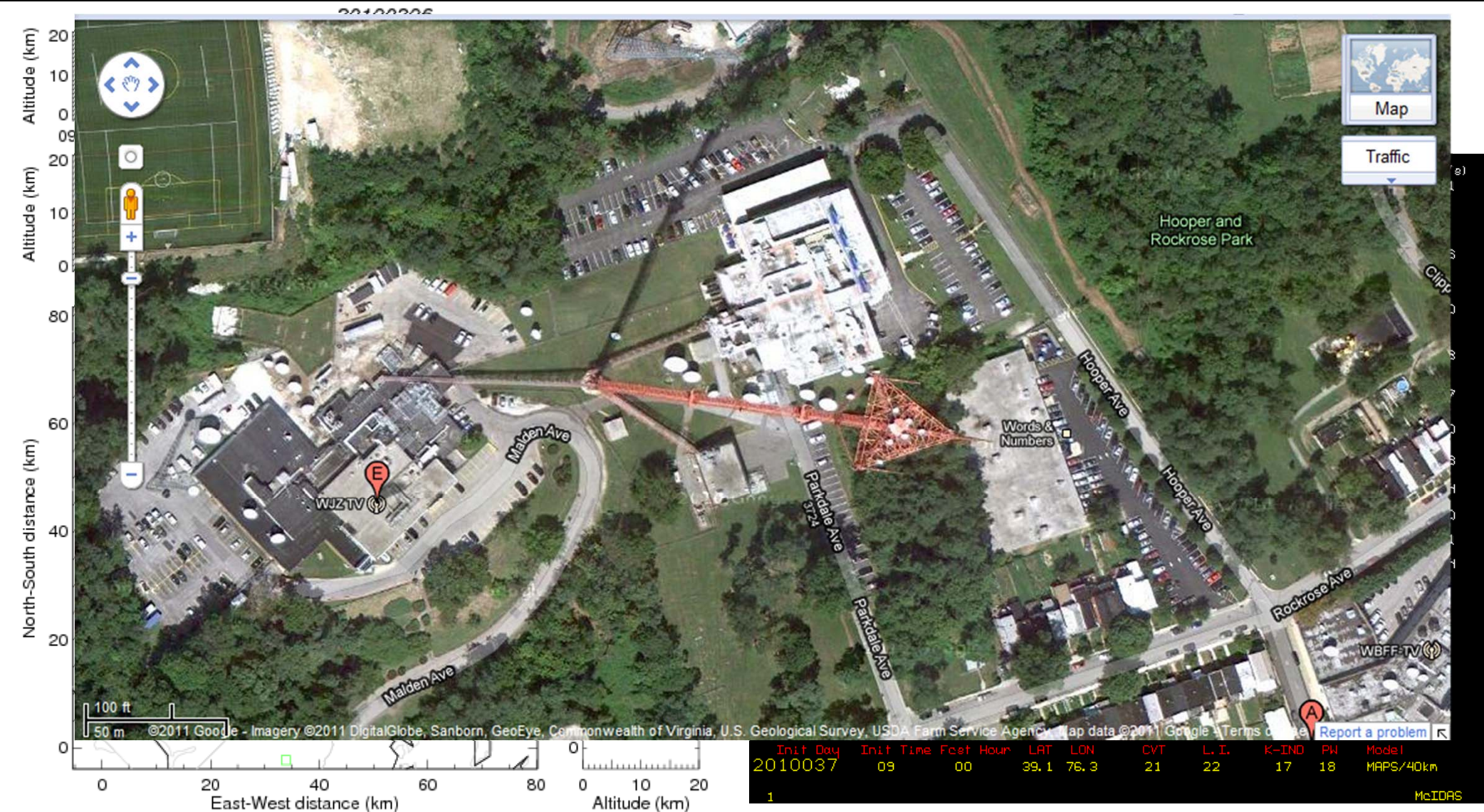
Tools and Datasets

■ Tools

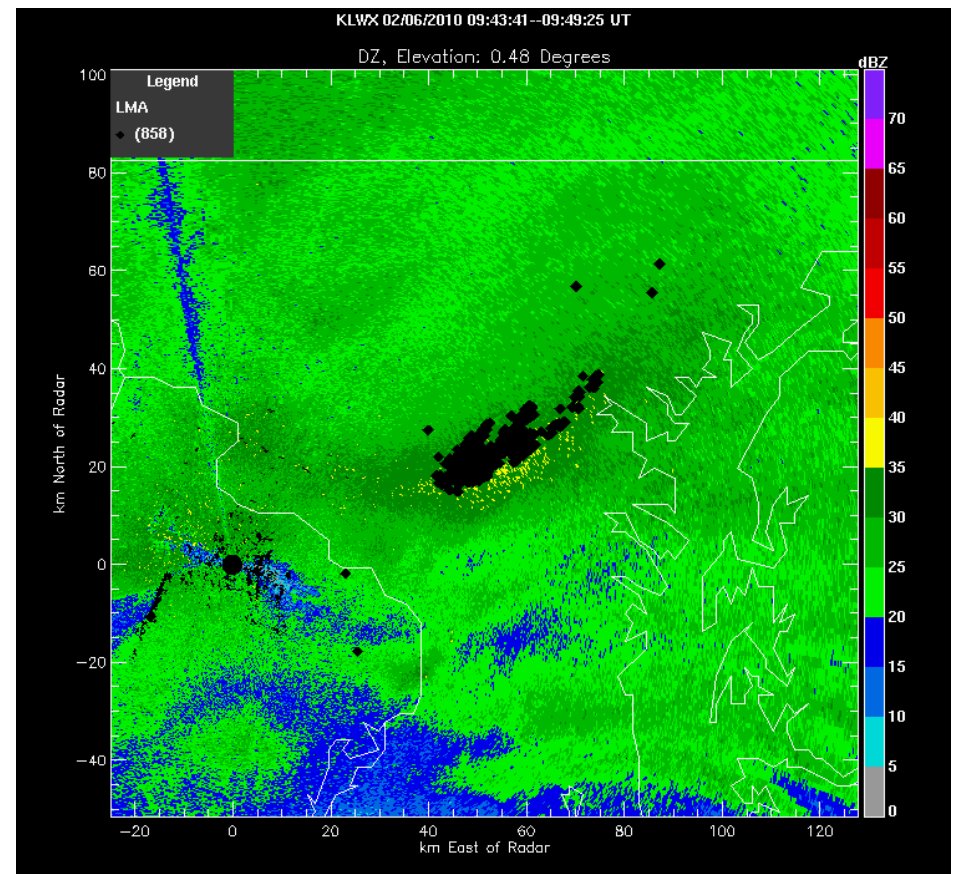
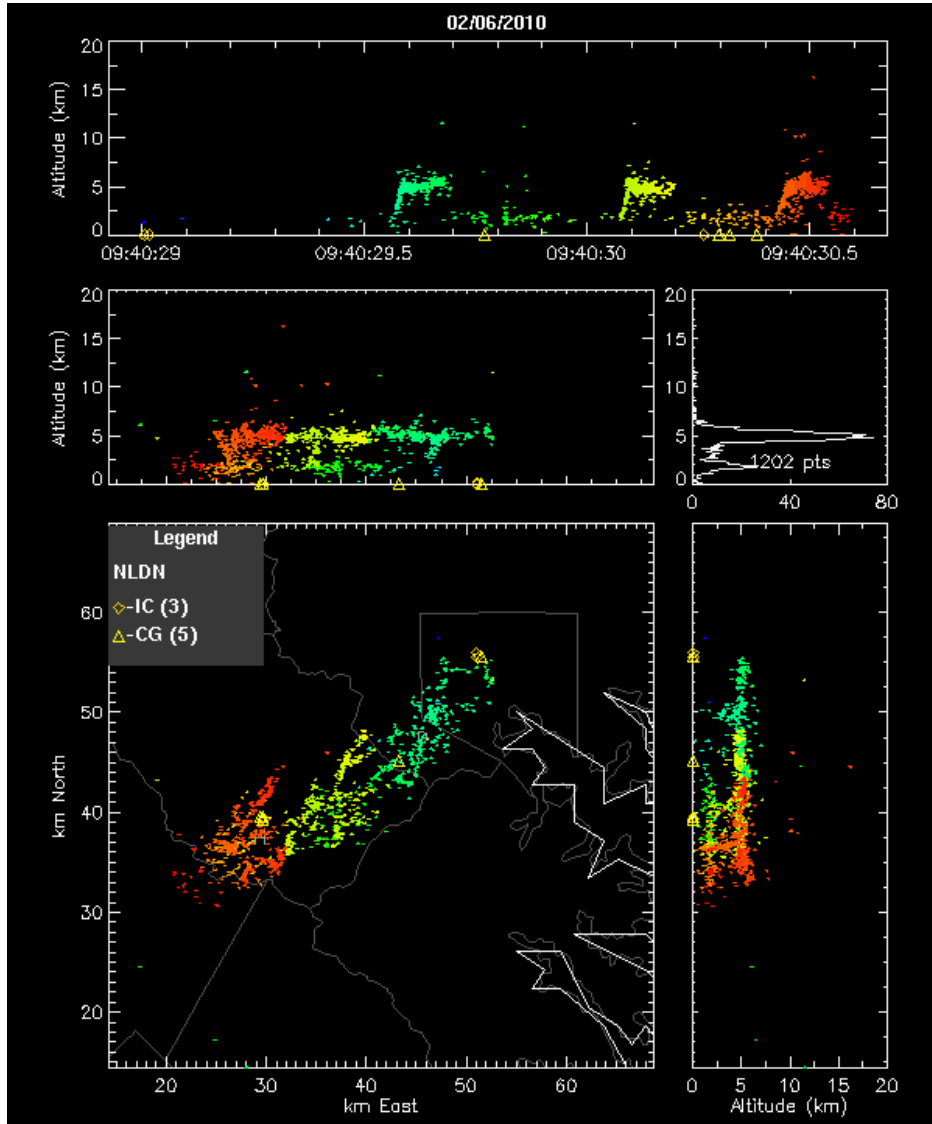
- Very high frequency lightning mapping arrays (VHF LMA, Washington DC and North AL; Rison et al. 1999)
- National Lightning Detection Network (NLDN; e.g., Cummins and Murphy 2009)
- WSR-88D network
- C-band Advanced Radar for Meteorological and Operational Research (ARMOR; Petersen et al. 2007) polarimetric radar (North Alabama only)



Baltimore, MD, February 6, 2010

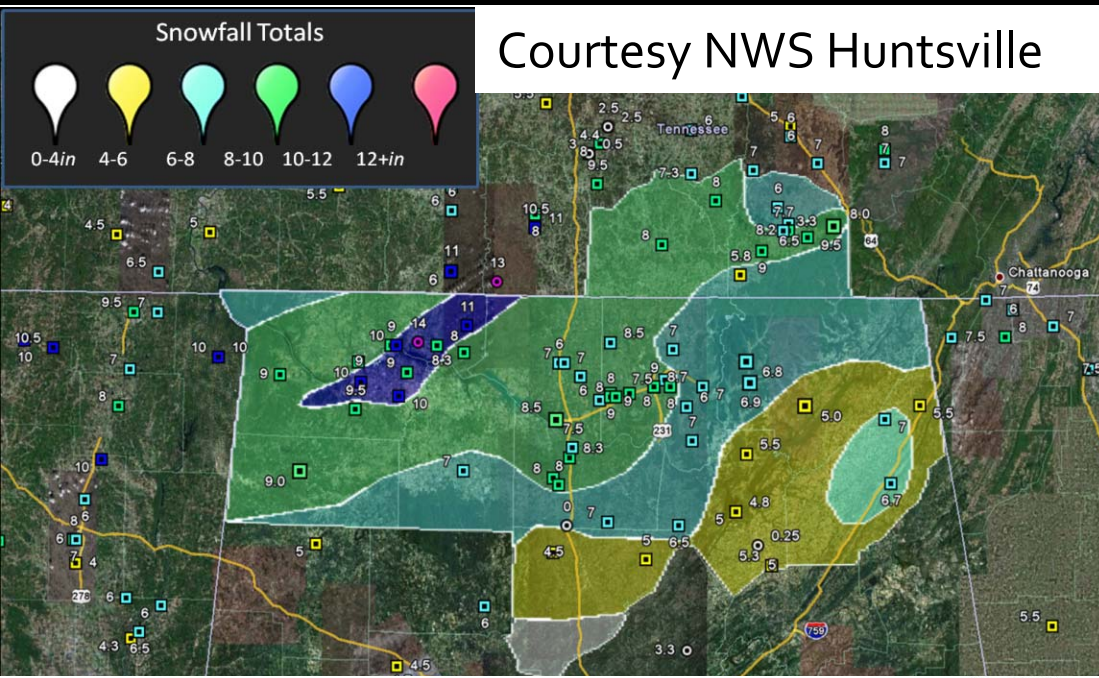


KLWX, 0943 UTC February 6, 2010



January 10, 2011

Huntsville, AL



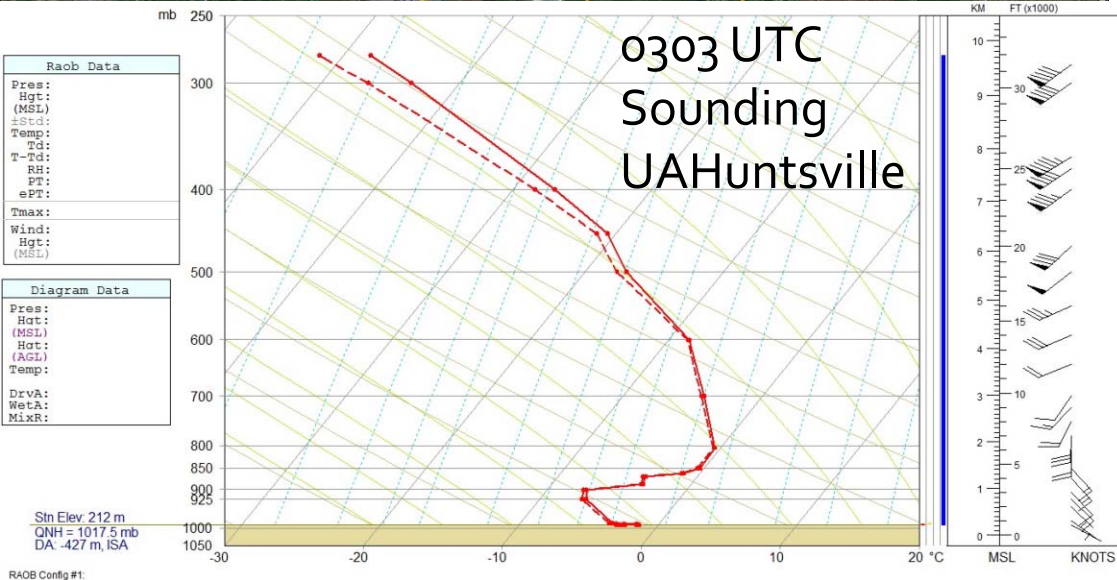
Heavy snowfall event, with snowfall rates on the order of $5\text{-}8\text{ cm hr}^{-1}$.

LMA, C-band polarimetric radar information, in situ radiosonde measurements available.

Flash statistics:

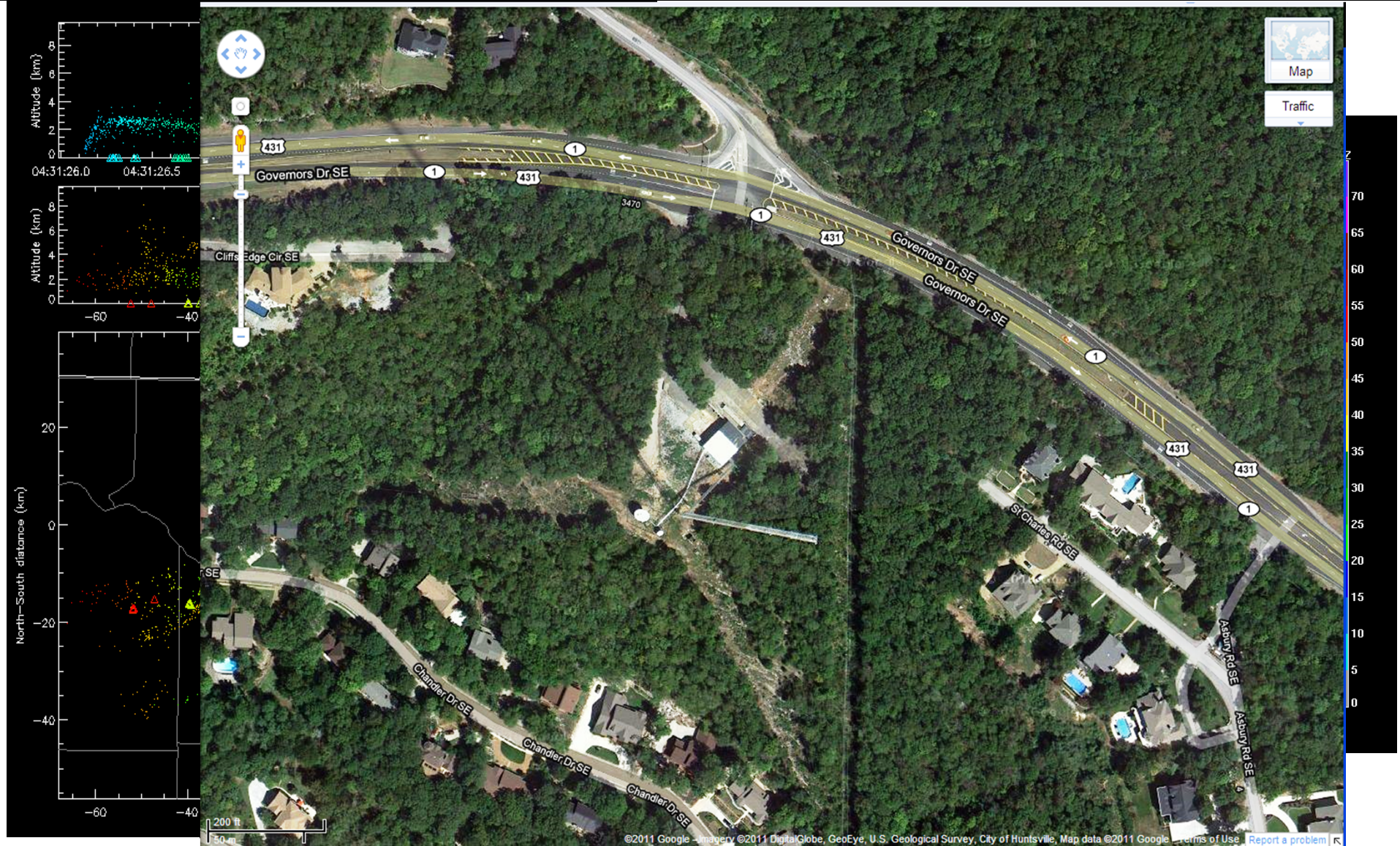
7 Flashes occurred within North Alabama LMA domain ($< 150\text{ km}$; $\geq 10\text{ VHF}$ sources to be called a flash).

- 5 of 7 flashes were detected by the NLDN
- 4 of 7 flashes initiate at a communications tower location
- 3 of 7 flashes have at least one downward CG component (not during initiation)
- All 3 of these flashes come to ground in the vicinity of another communications tower location ($< 0.5\text{ km}$)

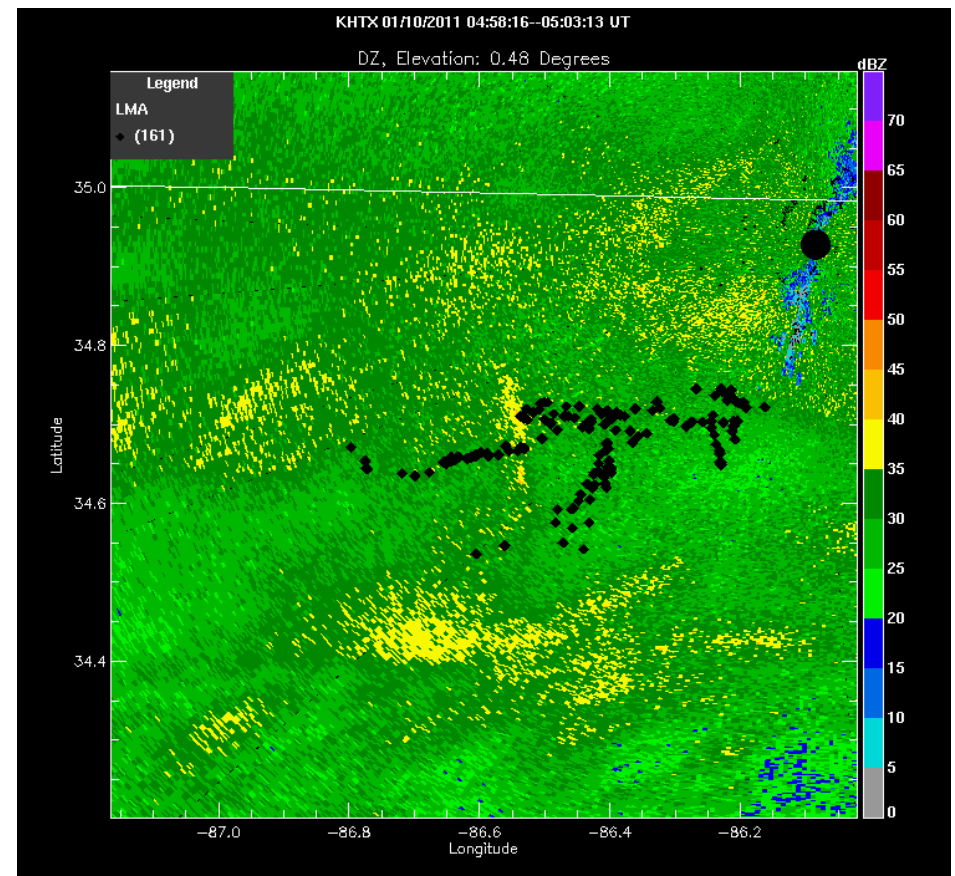
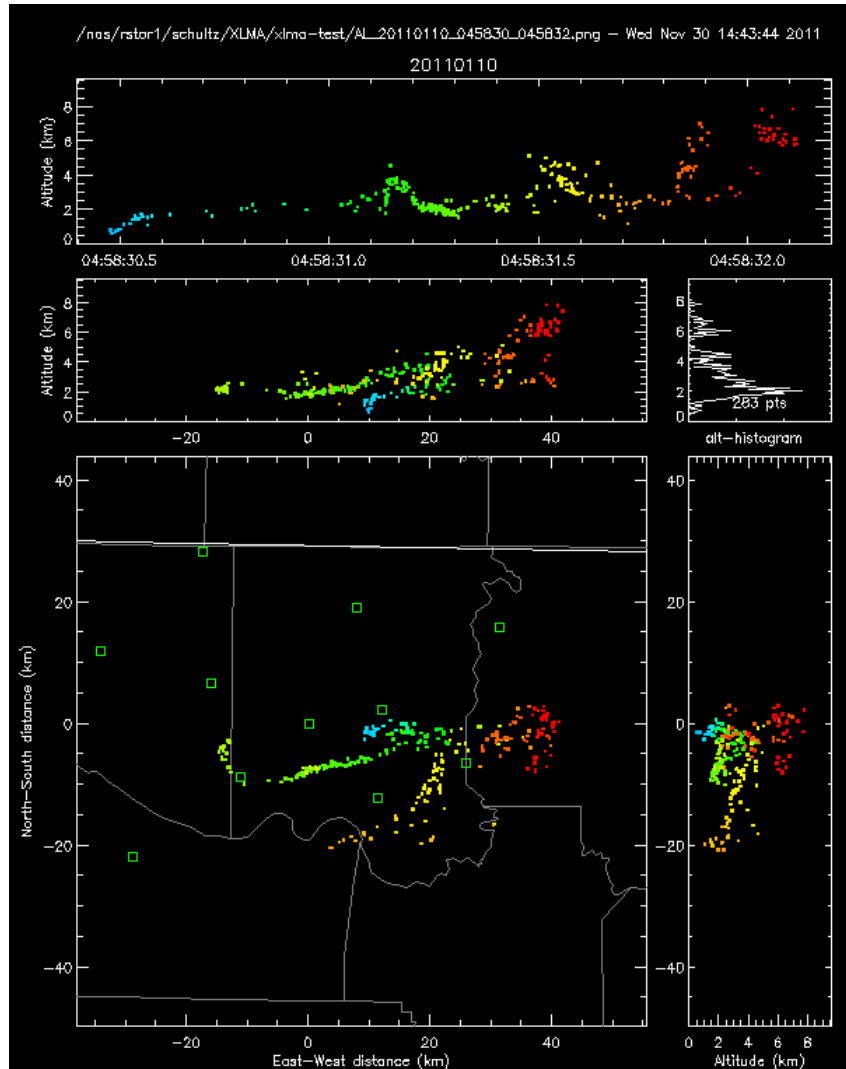


January 10, 2011, 0431 UTC

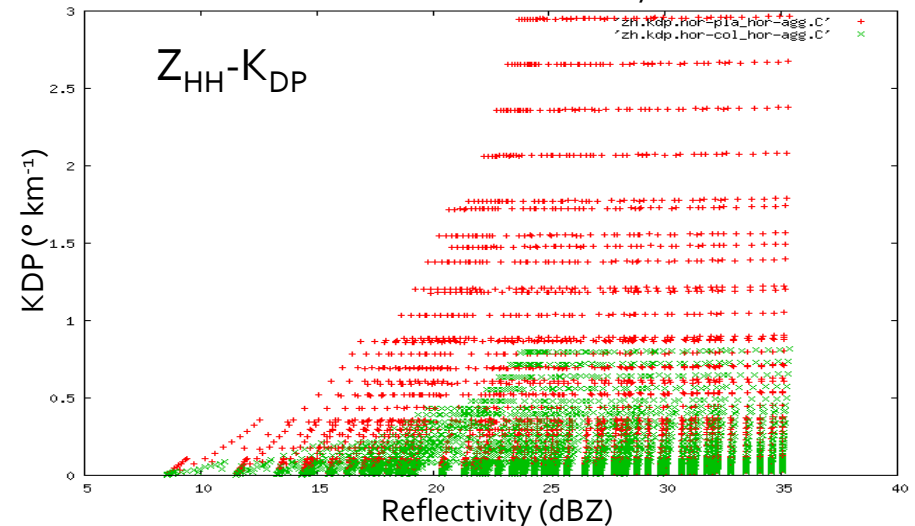
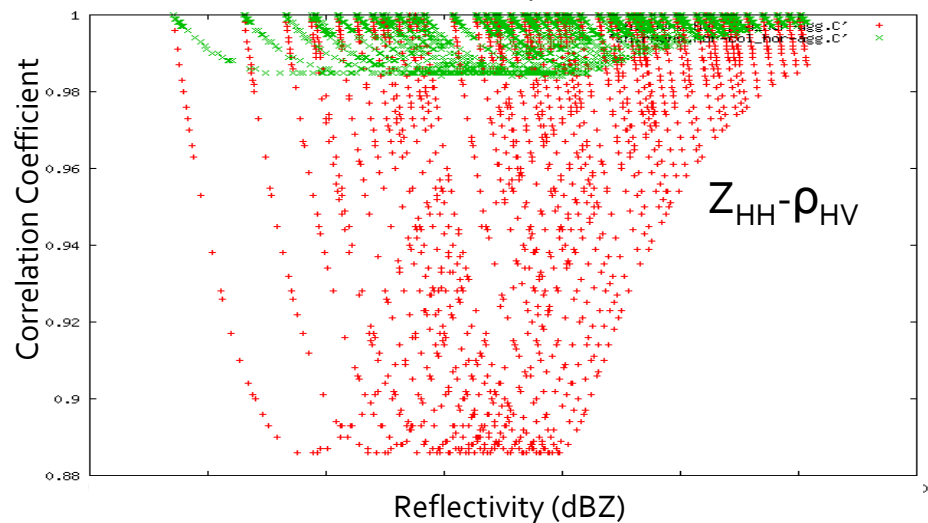
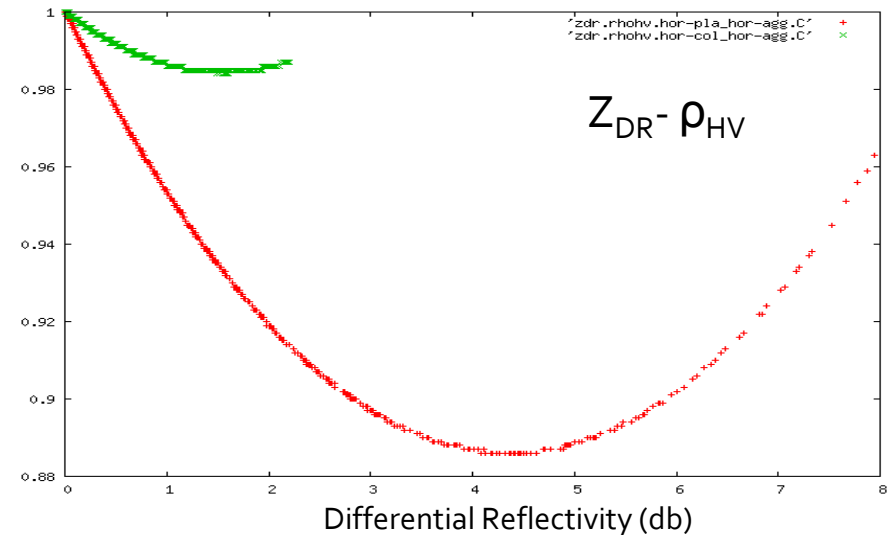
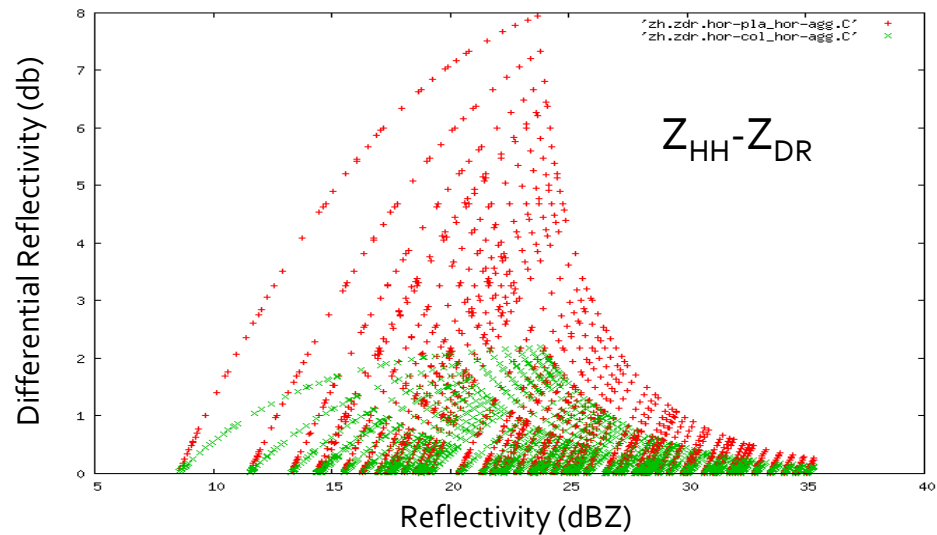
Huntsville, AL



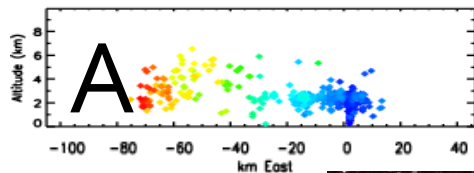
January 10, 2011, 0458 UTC



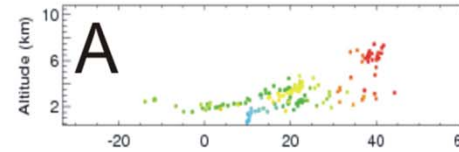
C-band Polarimetric T-Matrix



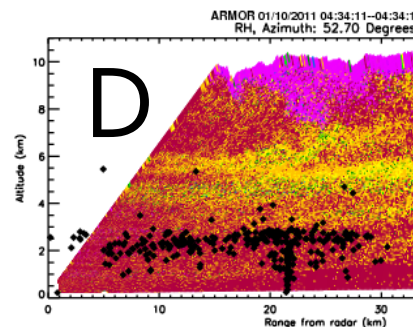
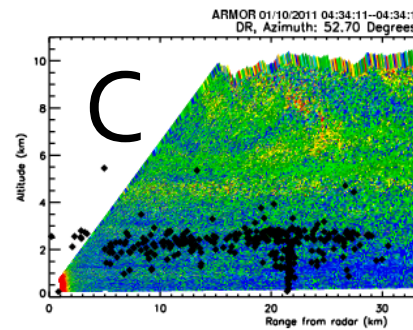
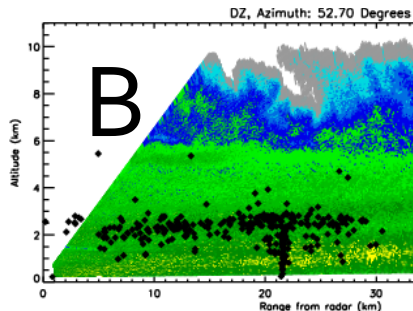
C-band Dual Polarimetric Measurements



04:31:26

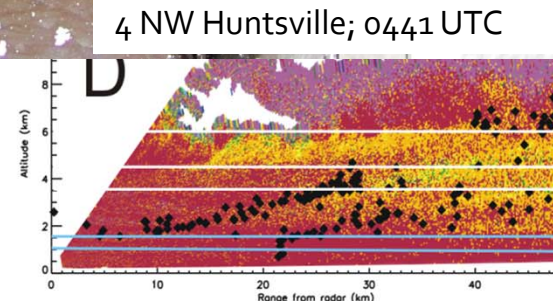


04:58:30



4 NW Huntsville; 0441 UTC

ρ_{hv}



Near -20°C, 93% RH
Near -10°C, water sat
Near -5°C, water sat
Near 0°C @ 303 UTC, water sat

Near -20°C, 93% RH
Near -10°C, water sat
Near -5°C, water sat
Near 0°C @ 303 UTC, water sat

Near -20°C, 93% RH
Near -10°C, water sat
Near -5°C, water sat
Near 0°C @ 303 UTC, water sat

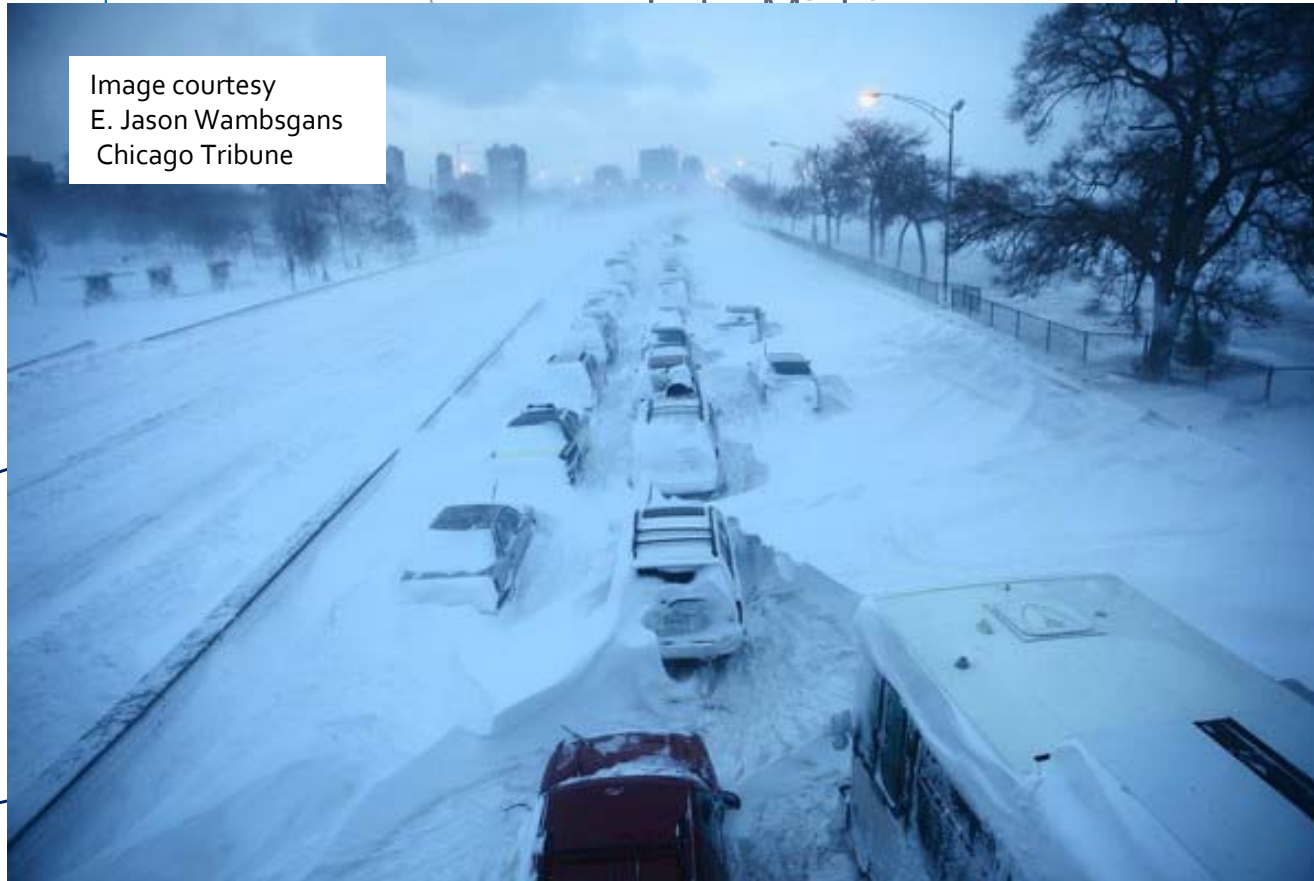
February 2, 2011 – Chicago, IL

2:00 UTC – 5:00 UTC

WGN
America

Moody
Bible
AM/FM
radio

Image courtesy
E. Jason Wambsgans
Chicago Tribune



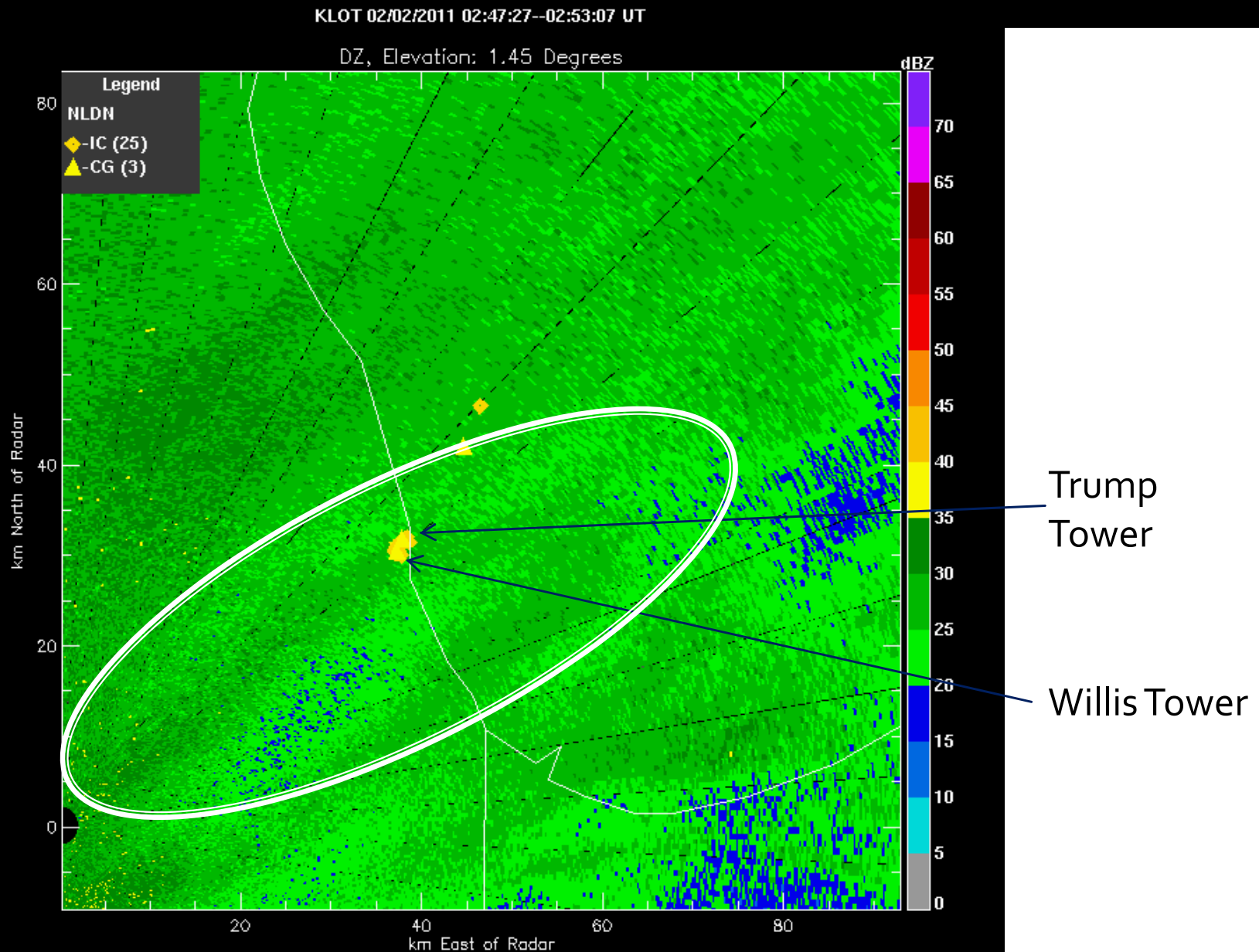
NLDN stroke
ations between
and 05 UTC
bruary 2, 2011

lis Tower

Mid America
Towers, Inc.

Jovon Communications

0247 UTC KLOT 1.45 degrees

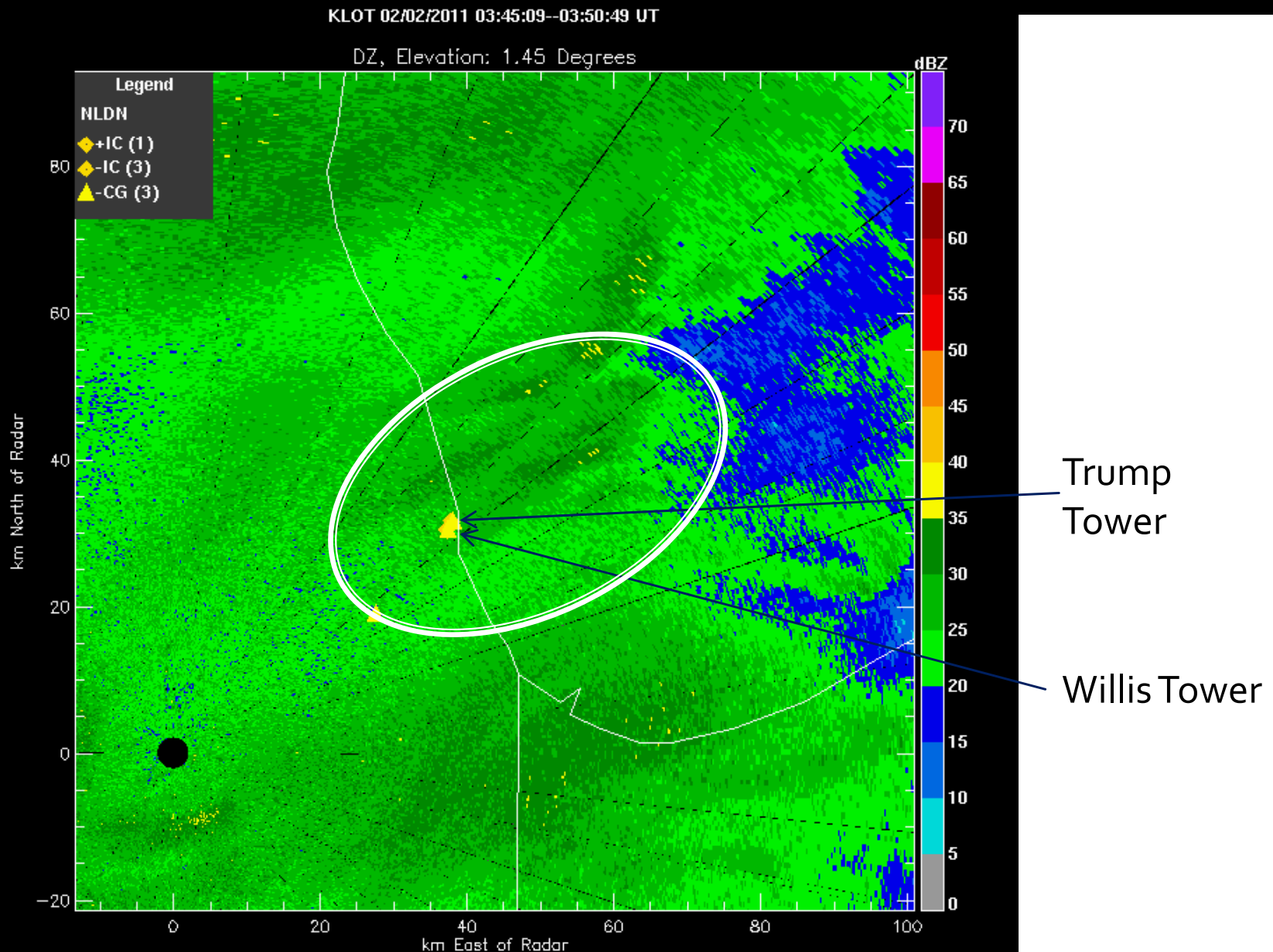


Banded feature
near towers

Near center of
the band axis

Displaced from
reflectivity
maximum

0345 UTC KLOT 1.45 degrees



Banded feature
near towers

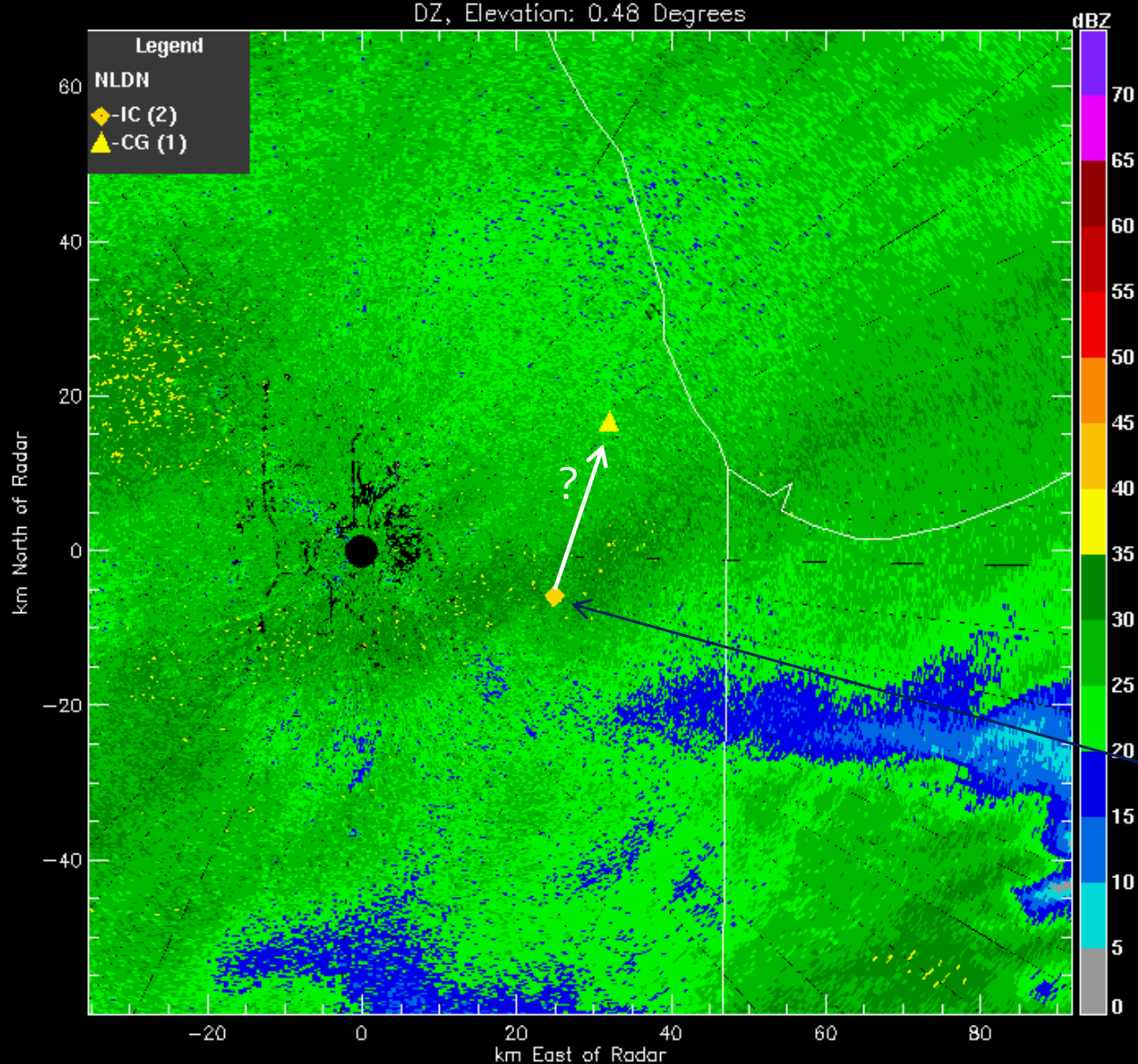
center of the
band axis

Displaced from
reflectivity
maximum

0415 UTC KLOT 0.48 degrees

KLOT 02/02/2011 04:13:58-04:19:37 UT

DZ, Elevation: 0.48 Degrees



Banded feature
over tower

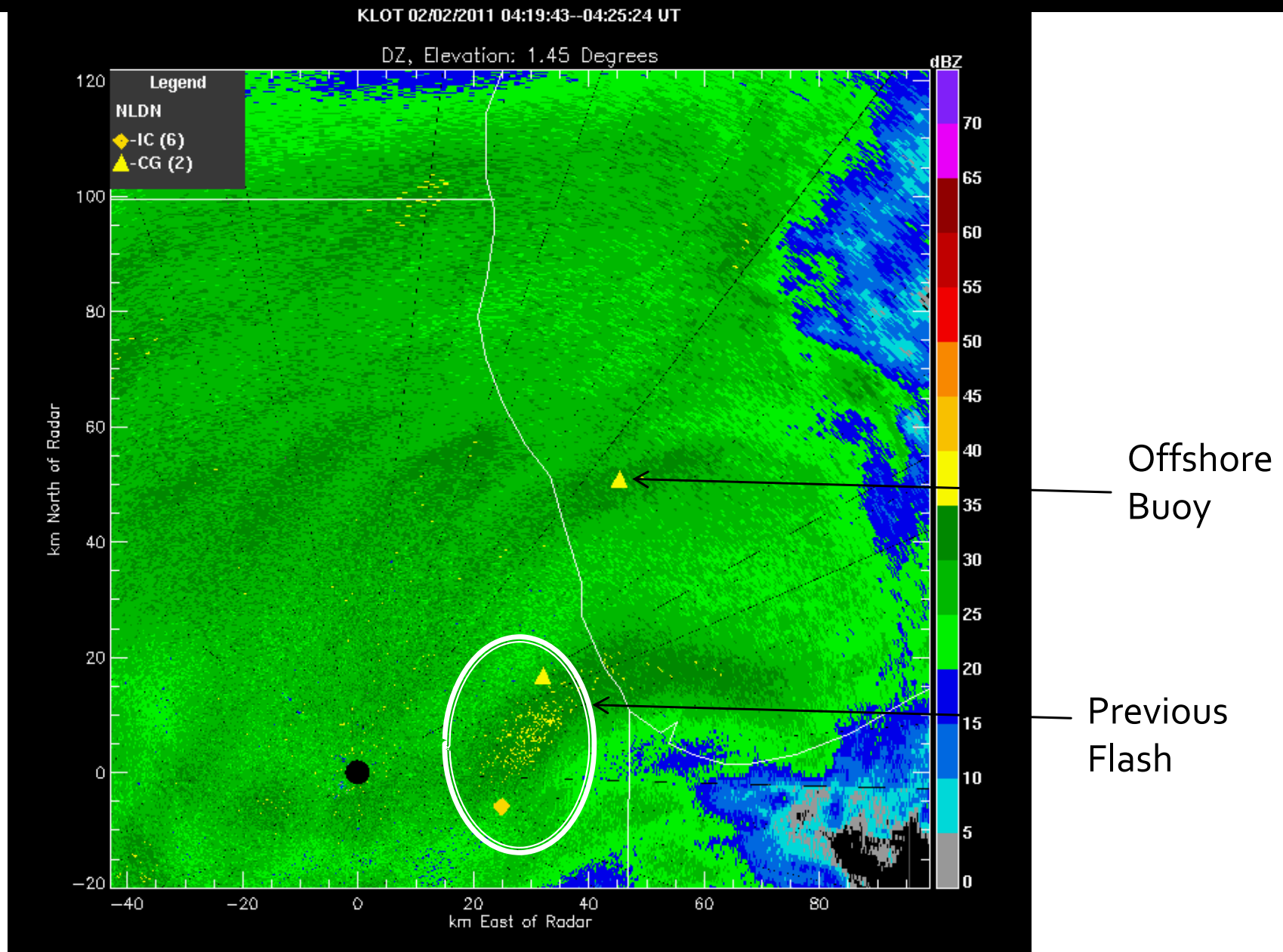
center of the
band axis

Secondary
flash displaced
from
reflectivity
maximum, and
within 100 ms
of initial flashes

Flashes in
close
temporal
proximity
and ~20 km
apart

Jovon
Communications

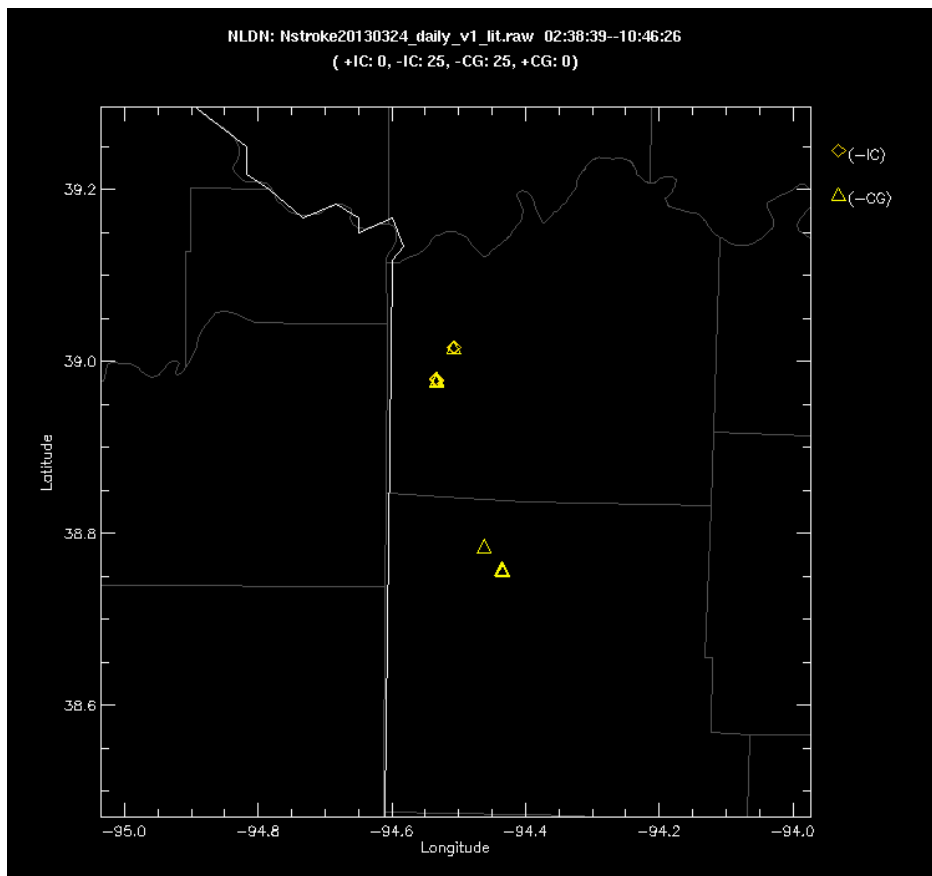
0419 UTC KLOT 1.45 degrees



Banded feature
over buoy

Center of the
band axis

Summary and Continuing Work



Tower flashes near Kansas City MO, March 24, 2013 snowstorm

- Tall structures play and important role in development of winter time lightning flashes
 - To what extent still needs to be assessed
- Tower initiated flashes typically occur as banded structures pass near/overhead
- Hi resolution RHI's from polarimetric radar show that the lightning has a tendency to propagate through layered structures within these snowstorms